USE OF PALM OIL CLINKER AS DRAINAGE LAYER IN GREEN ROOF SYSTEM

ANAS MOHAMAD HUSIAN KASSIM

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Faculty of Civil Engineering & Earth Resources
UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

Green roof has become widely used in most of modern countries in the world. It has many benefits in term of storm water management, urban heat island mitigation, and thermal performance which lead to energy conservation. The fact that Malaysia is being among one of the largest producer of palm oil in the world, Malaysia produces palm oil clinker as a waste materials as a by-product of extracting the oil. The palm oil clinker has the ability to replace the conventional material that had been used in the green roof system. This paper examines the usage of palm oil clinker to determine whether the palm oil clinker can replace the conventional materials (expanded clay, expanded shale, pumice, etc.). The ability for draining of palm oil clinker is studied since the purpose of drainage layer is to drain the excess water and to ensure aeration of substrate layer and roots. This study used an experimental procedure in which hydraulic conductivity, infiltration rate and bulk densities were measured. Besides, the experimental trays of selected green roof plants were also monitor to simulate the real green roof system. The results show that the palm oil clinker has a good ability of draining the excess water and there is no effect in term of plant development when the palm oil clinker is used as drainage layer.

ABSTRAK

Bumbung hijau telah digunakan secara meluas di kebanyakan negara-negara moden di dunia. Ia mempunyai banyak manfaat dari segi pengurusan air, bandar mitigasi pulau haba dan prestasi terma yang membawa kepada penjimatan tenaga. Hakikatnya Malaysia menjadi antara salah satu pengeluar terbesar minyak sawit dunia. Malaysia menghasilkan klinker kelapa sawit sebagai bahan-bahan buangan sebagai produk mengekstrak minyak. Klinker kelapa sawit mempunyai keupayaan untuk menggantikan bahan konvensional yang telah digunakan dalam sistem bumbung hijau. Thesis ini mengkaji penggunaan. Klinker kelapa sawit untuk menentukan sama ada ia boleh menggantikan bahan-bahan konvensional seperti tanah liat, syal, batu timbul dan lain-lain. Keupayaan saliran oleh klinker kelapa sawit dikaji kerana lapisan saliran adalah lapisan yang berfungsi untuk mengalirkan air yang berlebihan dan untuk memastikan pengudaraan lapisan substrat dan akar. Kajian ini menggunakan prosedur eksperimen dari segi konduksi hidraulik, kadar penyerapan dan ketumpatan pukal. Selain itu, kajian menggunakan dulang eksperimen tumbuhan bagi bumbung hijau juga dipilih bagi memantau proses simulasi sistem bumbung hijau yang sebenar. Keputusan menunjukkan bahawa klinker kelapa sawit mempunyai kemampuan yang baik bagi penyaliran air yang berlebihan dan tidak ada kesan dari segi pembangunan loji apabila klinker kelapa sawit digunakan sebagai lapisansaliran.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

During this era of development, there are a lot of green technology to be used in construction for the purpose of environmental benefit such as thermal performance, reduction of urban heat and electrical usage reduction. Since the beginning of educated life man was trying to alter the microclimate to be more "climate friendly" one, to avoid extreme climatic changes.

These changes have a direct effect on the climate of urban spaces for example the central parts of cities, causing a rise of the urban temperature and other alteration named as the heat island effect which describes built up areas that are hotter than nearby rural areas. This can cause climatic unpleasant conditions.

Nowadays, rising temperature and extreme changes in climate conditions made the developers to invent new technologies in order to reduce these changes. Green roof is one of the technologies that widely used these days in our building structures. Green roof is an effective solution of the problems at the building and urban levels. It is not only gives pleasant environment but also offer several benefits that the normal roofs don't. They reduce air pollution and noise, improve storm water management, increase vegetation and animal biodiversity in cities and they also reduce the carbon dioxide through photosynthesis. Green roofs can have great effect on the energy efficiency by reducing the heat transfer through the roof.

In some normal roofs the temperature can reach high values in summer seasons. Green roofs on the other hand have a huge impact on this temperature because of (soil thermal resistance, evapotranspiration, foliage shading). The heat flux that going through the roof is affected and that can change the indoor thermal condition and the building energy demand.

The green roof's soil, it is taken in by plant root systems, which absorb pollutants. This can help to improve water quality by reducing the pollutant volume entering nearby streams. Green roofs also create wildlife habitat, attracting pollinators, such as birds and bees. In addition to being aesthetically pleasing, commercial properties with green roofs can attract higher rents and maintain higher tenant retention.

On a hot day, an urban area can be 10 degrees hotter than the surrounding area due to human activities; green roofs stay substantially cooler (up to 40 – 50 degrees cooler) than conventional roofs helping to reduce the surrounding air temperature. This practice may also increase property values and reduce property maintenance fees. There are also energy saving benefits of green roofs. The life of the roof can be as much as doubled by adding a green roof, by protecting it from ultraviolet rays and thermal stress. Green roofs provide an extra layer of insulation that helps to reduce heating and cooling costs. By installing a green roof, you can help protect the environment and conserve water resources.

1.2 PROBLEM STATEMENT

Malaysia is one of the countries that located at the equator which considered as a dry hot climate all over the year with heavy rain on specific periods. That is why Malaysia is using air-conditioning in their building and that can increase the power consumption.

Green roof has been consolidated in recent years as a construction system that offers interesting advantages over traditional solutions. Some of these are the improvement of the urban environment and energy saving.

In the same time Malaysia is facing a waste material problem because there is no enough technology to reduce this waste material by recycling or reusing as substitution material in other material's component. Palm oil clinker is one of the waste materials that are going to be used in the green roof to substitute the Pumice drainage layer.

The main purpose of replacing the drainage layer is to examine whether the palm oil clinker is suitable for green roof system replacing the original material (Pumice) that has been used. And also to reduce and reuse the waste material that comes from Palm oil processing.

1.3 OBJECTIVES OF STUDY

The objectives of the study are:

1. To study the drainage ability when palm oil clinker is used as drainage layer.
2. To determine whether it is suitable to use palm oil clinker in green roof system.

1.4 SCOPE OF STUDY

Scopes of this study include the following procedure:

1. Drainage ability of palm oil clinker as drainage layer in green roof. The parameters to be evaluated such as hydraulic conductivity, infiltration rate, cumulative infiltration and bulk density.
2. Experimental green roof tray. The purpose of this experiment is to study the behavior of green roof system and evaluate the effect of replacing the porous materials with palm oil clinker.
3. Reducing the waste material and relating it to environment sustainability.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Green roofs are structures that have growing plant on the top side. These green roofs can have a lot of benefits that help to reduce the aspect of pollution in the urban environment. It has the ability of to monitor the storm water by reducing runoff and also green roof can be one of the technology that can conserve energy and have a potential cooling effect (Czerniel Berndtsson, 2010; Dunnet and Kingsbury, 2004; Getter and Rowe, 2006; Mentens et al., 2006; Oberndorfer et al., 2007; Rowe and Getter, 2010).

Some studies in US cities showed that with every one tree added per house the saving energy varies from 12% to 24% and in the same time reduce the cooling load between 17% to 57% (Akbari H, Kurn DM, Bretz SE, et al, 1997).

There are two types of green roof "intensive" or "extensive". Intensive green roof usually build in public places and it may include different types of trees and shrubs. It has more than 15 cm substrate depth and it required intense maintenance (Snodgrass and McIntyre, 2010). It is more expensive because of the design of the structure. On the other hand, extensive roofs have a substrate depth less than 15 cm and the vegetation above the roof is limited to grass and annuals due to the shallower depth. Extensive roofs have specific design and it is more commonly used in green roof.

An intensive green roof consists of a diversity of plants, including flowering shrubs and trees, and is usually intended for human interaction. As such, it must conform to applicable loading requirements. Intensive roofs are on flat roof surfaces or on a mild slope of up to 3%, and require a soil depth from 20-60 cm (8-24") (Peck and Kuhn, 2001, 5). Intensive green roofs generally require traditional landscaping maintenance and infrastructure such as water collection cisterns, reservoir boards, irrigation and fertilization (Nada Sutic, 2003).

Essentially, an intensive green roof is an actual rooftop garden, much like a typical garden, except that it happens to be on a roof, and it requires similar regular maintenance and upkeep. Intensive green roofs are more expensive than extensive gardens in both their creation and their maintenance. The growing medium is heavier because of its depth and composition (largely organic and soil based), and this means that the roof must be able to take on the load or be upgraded to bear the load. The saturated weight increase can be between 290 - 967.7 kg/m^2 (60-200 pounds per square foot [lbs/ft^2]) (Peck and Kuhn, 2001, 5). The plants are larger and usually more diverse, which makes them more expensive to purchase. Furthermore, intensive green roofs have expensive upkeep because of the regular maintenance requirements.

In comparison, extensive green roofs are lightweight, low maintenance and often inaccessible. Nada Sutic (2003) defines them as "lightweight veneer systems of thin layers of drought tolerant self-seeding vegetated roof covers using colourful sedums, grasses, mosses and meadow flowers requiring little or no irrigation, fertilization or maintenance."

Drought-resistant and alpine plants are favoured, because of low maintenance requirements. These types of plants are capable of handling a variety of arduous conditions including hot, dry and windy conditions, and they are good at storing water. Native plants seem to perform better than cultivars (Nada Sutic, 2003).

Extensive green roofs can be put onto roofs with slopes of up to 33%, and with little or no additional structural support (Nada Sutic, 2003). The growing medium of most extensive green roofs is a mineral-based mixture of sand, gravel, crushed brick, leca, peat organic matter and some soil, and varies in depth between five and 15 cm (2"-6") (Peck and Kuhn, 2001, 4).

The added wet weight (i.e. fully saturated) to a roof from an extensive roof usually ranges between 72.6 and 169.4 kg/m^2 (16-35 lbs/ft^2) (Peck and Kuhn, 2001, 4). Maintenance for an extensive roof is limited to watering in the first year, so that plants can become established, and occasional weeding of any invasive species in the following years. Extensive roofs are generally not intended as recreational space or to support people, trees or shrubs (Nada Sutic, 2003).

Table 1 shows summarize of the differences between extensive and intensive green roofs by listing their respective advantages and disadvantages.

Table 2.1: Differences between extensive and intensive green roofs

	Extensive Green Roof	**Intensive Green Roof**
Brief Description	• Thin soil, little or no irrigation, stressful condition for plants	• Deep soil, irrigation system, better condition for plants
Advantages	• Lightweight • Suitable for large areas • Suitable for roofs with 0-30 slope • Low maintenance • Often no need for irrigation and drainage systems • Relatively little technical expertise needed • Often suitable for retrofit projects • Can leave vegetation to develop spontaneously • Relatively inexpensive • Looks more natural • Easier for planning authority to demand green roofs be a condition for planning approvals	• Greater diversity of plants and soil • Good insulation properties • Can simulate a wildlife garden on the ground • Can be made very attractive • Often accessible • Diverse utilization of roof (ie for recreation, growing food, as open space) • Food gain-urban agriculture
Disadvantages	• More limited choice of plants • Usually no access for recreation or other users • Unattractive to some, especially in winter • Little or no opportunity for food gain	• Greater weight loading on roof • Need for irrigation and drainage systems, hence, greater need for energy water, materials, etc. • Higher cost • More complex systems and expertise required

Adapted from Peck et al., 1999. 14.

This technology was widely used in Germany and it worth $77 million in 2008 (CNN Technology 2008, R.Herman. 2003). It covers almost 13.5 km^2 of the flat area in Germany which equal to 14% of the flat roof. Generally, it is expensive roofs which considered as the preferred option since it is maintenance free and will last longer in the European climate (N.S.G Williams, J.P Rayner, et al, 2010).

2.2 Green Roof Systems

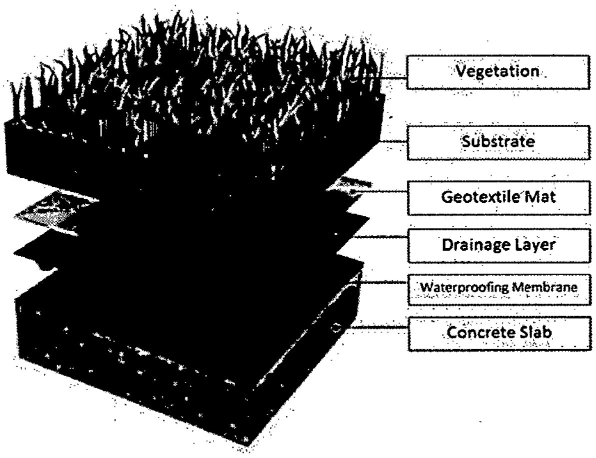

Figure 2.1: Green roof layers

The term 'green roof' will be used for extensive systems, and 'rooftop garden' for intensive systems (Christopher G. Wark and Wendy W. Wark . 2003). Green roof system includes:

i. Roofs cape is the landscape of the rooftop or the overall appearance of the roof.
ii. Modular system is when the vegetation and planting medium are contained in special trays covering all or most of the green roof. In a non-modular system, the planting medium is a continuous layer over the entire green roof. The rooftop garden below is a modular system.

iii. Eco-roof is another name for a green roof; this term is often used because many green roof designs involve plants that are not green for the entire year, particularly in northern regions.

2.3 Description of Components

The components used in extensive green roof are generally the same as those in intensive (Christopher G. Wark, Wendy W. Wark, 2003). The main different is in depth and project-specific design application and include the following:

2.3.1 Vegetation

A big variety of plants can be used for green roof. And the limitations are climate, structural design and maintenance budgets, and the roofscape designer's imagination. Since green roofs are lightweight, they often contain ground cover that can thrive in very shallow soils with little to no maintenance. Sedum, a succulent ground cover, as an example of good plant used widely in green roof.

2.3.2 Planting medium

The planting medium is distinguished by its mineral content, which is synthetically produced, expanded clay. The clay is considerably less dense and more absorbent than natural minerals, providing the basis for an ultra-lightweight planting medium.

On the other hand, Soil is also commonly used in high-maintenance rooftop gardens. The recommended thickness of soil for turfing is about 40 cm while for shrubs and trees ranges between 1 to 1.5 m. Extensive roof garden because of their light-weight nature uses a mixture of volcanic stones and pumice (Figure 2.2) and generally is able to sustain selected plant growth with a thickness of between 8 to 12 cm (Michael Wong, 2003).

Figure 2.2: Lightweight growing medium used for extensive roof gardens consisting mainly of volcanic stones and pumice

2.3.3 Filter layer

The filter layer is placed between the planting media and drainage layer, which allows water to flow through while retaining the planting medium, and serves as a root barrier. The filter usually comprises one or two layers of non-woven geotextile, where one of the layers may be treated with a root inhibitor (*i.e.* copper or a mild herbicide).

2.3.4 Containment

It refers to actual plant containers.

2.3.5 Drain Layer

The drain layer is placed between the planting medium and roof membrane which water can flow from anywhere on the green roof to the building's drainage system. Some systems simply use a layer of large-diameter expanded clay. The minimum drain layer thickness is usually less than 20 mm (0.8 in), but a thicker mat can provide additional insulation and root restriction.

2.3.6 Protective Layer

The roof's membrane needs protection, primarily from damage during green roof installation, but also from fertilizers and possible root penetrations. The protective layer can be a slab of lightweight concrete, sheet of rigid insulation, thick plastic sheet, copper foil, or a combination of these, depending on the particular design and green roof application.

2.3.7 Insulation

The thermal protection provided by the vegetation, planting medium, and drain layer sufficiently eliminates the need for additional insulation in warm, dry climates. However, building codes usually require a certain level of added insulation, regardless of the overall roof design.

2.3.8 Waterproofing

A green roof can be installed with any kind of waterproofing system, but single-ply membranes have become very popular in recent years and are specified by nearly all green roof companies for their cost effectiveness and simplicity. As such, the waterproofing layer is typically assumed to be a membrane.

2.3.9 Irrigation

Passive irrigation describes the process of storing rainwater in the drain layer, which eventually wicks back up through the planting medium while excess is allowed to drain off.

Irrigation is rarely necessary, however, when drought-tolerant plants like sedums are used. All these elements need not be acquired as individual units, as some products and designs on the market combine the functions of two or more components. Combination designs can often reduce the weight and cost of a system.

2.4 Materials

It includes different types of layers which are vegetation layer, substrate layer, filter layer, protection layer, drainage layer and lastly waterproofing layer. Vegetation layer, as the growing plant layer can be trees, plants and even grass. Then the substrate layer is topsoil or garden soil.it is the physical support for the plant. It provides nutrients and has the capacity to retain water. Filter layer usually polypropylene or polyester geotextiles membrane.it allows the water to cross but not of the substrate small particulates that could clog the cavities in the drainage layer.

Protection layer usually geotextiles polypropylene or polyester membrane. It provides mechanical protection of lower layers, especially for the waterproofing layer. Drainage layer is specified to obtain a balance between air and water in the green roof system.it should be able to slow the water when it rains and in the same time unsure good drainage of the substrate and roots. There are two types of drainage layers commonly used which are polyethylene (polystyrene nodular panels) and porous stone material layer. Lastly the waterproofing layer, which protects the building from the roots and water, usually bitumen or PVC membrane is being used reinforced with polyester, fiber glass, plastic , and mineral granules (Minke G.Hauser mit grunem Pelz, Frankfurt, 1982; e.V (FLL), 2008.

To date, green roof research has been using different kind of materials as drainage layer, in order to compare the ability of this materials with the original materials used , hydraulic conductivity was studied with a constant load permeameters (Vila A, Perez G, Sole, et al, 2012). The material that were used in the first work were a volcanice porous gravel (P) named puzolana with a size of 4-12mm and also recycled rubber of tires (R) with different sizes, 2-7mm as (R-big) , between 2-3.4mm (R-half) and lastyly 0.8-2.5mm (R-small). Individual experiments were done for each the drainage materials. On the other hand, to further study the behavior of the roof system and examine the different if we replace the puzolana by the rubber crumbs as drainage later. Experimental trays were tested during summer and autumn (Vila A, Perez G, Sole, et al, 2012).

One of the main solutions used as drainage layer is a puzolana or porous stone materials. Due to the excessive demand of these materials and landscape destruction and the consequences arise from the later processing. Waste products that are not commercialized are interesting to be an alternative for the natural materials. A clear example is waste tires and the possibility of using it as drainage layer in green roof substituting the materials currently used (Richter AY, Weaver RW, 2003).

2.4.1 Palm Oil Clinker

This region, a lot of emphasis has been given towards using agricultural waste as building materials. Research has been carried out for studying the utilization of agricultural wastes such as rise husk, palm oil fiber and palm oil shells to be used in structural lightweight concrete (Arthur Chan Teng, 2010).

Malaysia is the second largest palm oil producing country in the world and it produces more than half of world's palm oil. The production of palm oil result in by products such as empty fruit bunches, palm kernel shells or palm shells, pericarp, palm oil mill effluent and palm oil clinker. On pf the ways to dispose these wastes would be utilization of some of these into constructive building materials or having these materials to replace some conventional materials. This will also help to prevent the depletion of natural resources and to maintain ecological balance (Arthur Chan Teng, 2010).

Palm oil clinker is a local waste material which is produced from palm oil extraction industry. It is an artificial aggregate. According to lightweight aggregate classification, palm oil clinker is categorized under unprocessed by-product material. In palm oil mill, the palm oil shell together with the husk, which has been squeezed were used as burning fires in the furnace. After burning for 4 hours at 400 c, porous lumps are formed, known as clinker. The clinker no longer is bio-material since it has undergone permanent change in state during the burning period. The porous texture condition and low density are the main properties that make the clinker suitable to be used as lightweight aggregate as prescribed in BS1165(1966 (Arthur Chan Teng, 2010).

Palm oil clinker is a new material and most of its properties are not well known. There are no mix specifications from the manufacturers and there are no existing experimental data. Accurate determination of the properties of the aggregate such as specific gravity, unit weights and water absorption are very difficult because of its novelty and wide variability of its behavior. This waste is expected to be on its increase as the country desires to produce renewable energy from biological sources (Arthur Chan Teng, 2010). The eradication of this waste is very important in order to provide decent environment for the people.

2.4.1.1 Palm oil clinker aggregate

Palm oil clinker is obtained from by-product of palm oil milling (Arthur Chan Teng, 2010). The aggregates produced from clinker are lightweight, porous and irregular in shape, and consequently have low values of bulk density and specific gravity (Arthur Chan Teng, 2010). In Malaysia, the development of using palm oil clinker as lightweight aggregate in construction industry, especially in structural application started about 30 years ago (Arthur Chan Teng, 2010). The properties of fine and coarse palm oil clinkers are shown in Table below:

Table 2.2: Properties of fine and coarse palm oil clinkers

Aggregate properties	Fine palm oil clinker	Coarse palm oil clinker
Specific gravity	1.75	1.73
Absorption –SSD (%)	14.29	5.39
Bulk density (kg/m^3)	1122.10	793.14
Voids in aggregate (%)	35.75	54.06

Adapted from Abdullahi et al., 2009

2.4.1.2 Collection and preparation of clinker

In the research of others, all clinkers were taken from the burning boiler were in the form of hard clinker and need to be crushed into smaller size. The clinkers were first crushed by using hammer to a size that can be fit into grind machine. Then, a grind machine was used to crush all the clinker to the required size.

The clinker aggregate were then sieved using BS 410 sieve size in order to segregate the aggregate to the required size. Clinker with nominal size of 10mm was